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RESEARCH MEMORANDUM

for the

U. S. Air Force

INTERIM REPORT ON FREE-SPINNING AND RECOVERY CHARACTERISTICS OF A 1/18-SCALE MODEL OF THE RYAN X-13 AIRPLANE AS DETERMINED FROM TESTS IN THE LANGLEY 20-FOOT FREE-SPINNING TUNNEL

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

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INTERIM REPORT ON FREE-SPINNING AND RECOVERY CHARACTERISTICS OF A 1/18-SCALE MODEL OF THE RYAN X-13 AIRPLANE AS DETERMINED FROM TESTS IN THE LANGLEY 20-FOOT FREE-SPINNING TUNNEL

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SUMMARY

An investigation is being conducted in the Langley 20-foot free-spinning tunnel on a 1/18-scale model of the Ryan X-13 airplane to determine its spin and recovery characteristics. The spin and recovery characteristics determined to date are presented in this report.

Model test results indicate that two types of spins may be possible: one, a fairly steady flat spin; and the other, a violently oscillatory spin. Recoveries by rudder reversal or by rudder reversal accompanied by moving the elevator down may not be possible when ailerons are deflected against the spin. Satisfactory recoveries can be obtained by reversing the rudder to full against the spin and simultaneously moving the ailerons to full with the spin. The controls should be neutralized immediately after recovery in order to avoid entering a spin in the opposite direction. The extension of the landing gear will have little or no effect on the spin and recovery characteristics of the airplane.

INTRODUCTION

In accordance with a request by the U. S. Air Force, an investigation is being conducted to determine the spin and recovery characteristics of a 1/18-scale model of the Ryan X-13 airplane. Test results previously completed to determine the size parachute required for emergency spin recovery during demonstration spins were presented in reference 1. The spin and recovery characteristics for the normal-weight loading with hook are presented in this report. The engine gyroscopic effects were not simulated.

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An appendix is included which presents a general description of the model testing technique, the precision with which model test results and mass characteristics are determined, variations of model mass characteristics occurring during tests, and a general comparison between model and airplane results.

SYMBOLS

b — wing span, ft

S — wing area, ft^2

$\bar{c}$ — mean aerodynamic chord, ft

$x/\bar{c}$ — ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord; x is measured in wing chord plane

$z/\bar{c}$ — ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below line)

m — mass of airplane, slugs

I_X, I_Y, I_Z — moments of inertia about X, Y, and Z body axes respectively, slug-ft^2

$\dfrac{I_X - I_Y}{mb^2}$ — inertia yawing-moment parameter

$\dfrac{I_Y - I_Z}{mb^2}$ — inertia rolling-moment parameter

$\dfrac{I_Z - I_X}{mb^2}$ — inertia pitching-moment parameter

ρ — air density, slug/cu ft

μ — relative density of airplane, $\dfrac{m}{\rho S b}$

α — angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg

ϕ — angle between span axis and horizontal, deg

V	full-scale true rate of descent, ft/sec
Ω	full-scale angular velocity about spin axis, rps

MODEL AND TEST CONDITIONS

The 1/18-scale model of the Ryan X-13 airplane was built at the Langley Laboratory of the National Advisory Committee for Aeronautics. A three-view drawing of the model is shown in figure 1 and a photograph of the model as tested is shown in figure 2. The dimensional characteristics of the airplane are presented in table I.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 25,000 feet ($\rho = 0.001065$ slug/cu ft). The loading conditions possible on the X-13 airplane and the loading tested on the model are presented in table II.

A remote-control mechanism was installed in the model to actuate the controls for the recovery attempts. Sufficient hinge moments were exerted on the controls for the recovery attempts to reverse them fully and rapidly.

The ailerons and elevators are combined into one control known as elevons. (See fig. 1.) In determining the control deflection of the elevons, the movement of the ailerons and elevators are additive. The maximum control deflections (measured perpendicular to the hinge line) used were:

Rudder, deg	25 right, 25 left
Ailerons, deg	17.5 up, 17.5 down
Elevators, deg	22.5 up, 2.5 down

RESULTS AND DISCUSSION

The results of the spin and recovery tests are presented in chart 1. Spins to the right and left were similar and the results are arbitrarily presented in terms of right spins. Only brief tests were conducted with the normal center-of-gravity position of 32.5 percent mean aerodynamic chord because developed model spins could be obtained for this center-of-gravity position only after numerous attempts. In order to expedite the test program, tests were conducted for a center-of-gravity position of 29.5 percent $\bar{c}$ where spins could be obtained more readily than for the normal center-of-gravity position. The results are considered to be representative of those obtainable for the normal center-of-gravity position, inasmuch as the spin and recovery characteristics were generally similar to those for the normal center-of-gravity position.

The results indicate that two types of spins may be possible on the airplane, one a fairly steady flat spin and the other a violently oscillatory spin. Both types of spins were obtained with the ailerons deflected to full against the spin but for other aileron settings, when a spin was obtained, only the more steady type of spin was indicated as being possible.

The model results show that it may not be possible to recover from a developed spin by reversal of the rudder alone. Aileron against the spin deflections were adverse to recovery and should be avoided on spins of this airplane. Moving the ailerons to with the spin in conjunction with reversal of the rudder, however, resulted in satisfactory recovery characteristics when the ailerons were moved to at least two-thirds with the spin. Tests in which the ailerons alone were moved to with the spin indicated that the ailerons are the primary control for recovery. When ailerons were moved with the spins during recovery attempts, the model almost invariably entered a spin in the opposite direction after recovering from the initial spin. This indicated that the pilot must neutralize controls on the airplane immediately after recovery and exercise extreme caution to avoid entering a spin in the opposite direction. An analysis of the effects of elevator movement on the recovery characteristics showed that rudder reversal accompanied by movement of the elevator down would be inadequate for satisfactory recovery.

The optimum control technique for recovery is reversal of the rudder to full against the spin and simultaneous movement of the ailerons to full with the spin, followed by moving the elevator to neutral. The airplane may very quickly enter a spin in the opposite direction and the pilot should neutralize all controls immediately after recovery.

Effect of landing gear.- An analysis based on reference 2 indicates that the landing gear will have little or no effect on the spin and recovery characteristics of this airplane.

CONCLUSIONS

Based on the results of tests of a 1/18-scale model of the Ryan X-13 airplane, the following conclusions regarding the spin and recovery characteristics of the airplane at an altitude of 25,000 feet are made:

1. Two types of spins may be possible on the airplane, one a fairly steady, flat spin and the other a violently oscillatory spin.

2. Ailerons-against deflections should be avoided during spins.

3. The optimum control technique for recovery is reversal of the rudder to full against the spin and simultaneous movement of the ailerons

to full with the spin followed by moving the elevator to neutral. The airplane may very quickly enter another spin in the opposite direction, however, and caution should be exercised to avoid entering another spin by neutralizing all controls immediately after recovery.

4. The spin and recovery characteristics of the airplane will not be appreciably affected by extension of the landing gear.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., July 27, 1955.

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for Thomas A. Harris
Chief of Stability Research Division

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APPENDIX

METHODS AND PRECISION

Model Testing Technique

The operation of the Langley 20-foot free-spinning tunnel is generally similar to that described in reference 3 for the Langley 15-foot free-spinning tunnel except that the model-launching technique is different. With the controls set in the desired position, a model is launched by hand with rotation into the vertically rising air stream. After a number of turns in the established spin, a recovery attempt is made by moving one or more controls by means of a remote-control mechanism. After recovery, the model dives into a safety net. The tests are photographed with a motion-picture camera. The spin data obtained from these tests are then converted to corresponding full-scale values by methods described in reference 3.

Spin-tunnel tests are usually performed to determine the spin and recovery characteristics of a model for the normal spinning-control configuration (elevator full up, lateral controls neutral, and rudder full with the spin) and for various other lateral control and elevator combinations including neutral and maximum settings of the surfaces. Recovery is generally attempted by rapid full reversal of the rudder, by rapid full reversal of both rudder and elevator, or by rapid full reversal of the rudder simultaneously with moving ailerons to full with the spin. The particular control manipulation required for recovery is generally dependent on the mass and dimensional characteristics of the model (refs. 4 and 5). Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For these tests, the elevator is set at either full up or two-thirds of its full-up deflection and the lateral controls are set at one-third of full deflection in the direction conducive to slower recoveries, which may be either against the spin (stick left in a right spin) or with the spin depending primarily on the mass characteristics of the particular model. Recovery is attempted by rapidly reversing the rudder from full with the spin to only two-thirds against the spin, by simultaneous rudder reversal to two-thirds against the spin, and movement of the elevator to either neutral or two-thirds down, or by simultaneous rudder reversal to two-thirds against the spin and lateral-stick movement to two-thirds with the spin. This control configuration and manipulation is referred to as the "criterion spin," with the particular control settings and manipulation used being dependent on the mass and dimensional characteristics of the model.

Turns for recovery are measured from the time the controls are moved to the time the spin rotation ceases. Recovery characteristics of a model are generally considered satisfactory if recovery attempted from the criterion spin in any of the manners previously described is accomplished within $2\frac{1}{4}$ turns. This value has been selected on the basis of full-scale-airplane spin-recovery data that are available for comparison with corresponding model test results.

When a model recovers without control movement (rudder held with the spin), the results are recorded as "no spin." When a model continues to spin for 10 or more turns after the controls are moved for recovery, the result is recorded as ∞.

Precision

Results determined in free-spinning tunnel tests are believed to be true values given by models within the following limits:

α, deg	± 1
ϕ, deg	± 1
V, percent	± 5
Ω, percent	± 2
Turns for recovery obtained from motion-picture records	$\pm\frac{1}{4}$
Turns for recovery obtained visually	$\pm\frac{1}{2}$

The preceding limits may be exceeded for certain spins in which it is difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

The accuracy of measuring the weight and mass distribution of models is believed to be within the following limits:

Weight, percent	± 1
Center-of-gravity location percent $\bar{c}$	± 1
Moments of inertia, percent	± 5

Controls are set with an accuracy of $\pm 1^{\circ}$.

Variations in Model Mass Characteristics

Because it is impracticable to ballast models exactly and because of inadvertent damage to models during tests, the measured weight and mass distribution of the Ryan X-13 model varied from the true scaled-down values within the following limits:

Weight, percent	1 to 2 high
Center-of-gravity location, percent $\bar{c}$	1 forward
Moments of inertia:	
I_X, percent	3 to 15 high
I_Y, percent	0 to 7 high
I_Z, percent	12 to 5 low

Comparison Between Model and Airplane Results

Comparison between model and full-scale results in reference 6 indicated that model tests accurately predicted full-scale recovery characteristics approximately 90 percent of the time and that for the remaining 10 percent of the time, the model results were of value in predicting some of the details of the full-scale spins, such as motions in the developed spin and proper recovery techniques. The airplanes generally spun at an angle of attack closer to 45° than did the corresponding models. The comparison presented in reference 6 also indicated that generally the airplanes spun with the inner wing tilted more downward and with a greater altitude loss per revolution than did the corresponding models, the higher rate of descent however, generally being associated with the smaller angle of attack regardless of whether it was for the airplane or the model.

REFERENCES

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2. Gale, Lawrence J.: Effect of Landing Flaps and Landing Gear on the Spin and Recovery Characteristics of Airplanes. NACA TN 1643, 1948.

3. Zimmerman, C. H.: Preliminary Tests in the N.A.C.A. Free-Spinning Wind Tunnel. NACA Rep. 557, 1936.

4. Neihouse, A. I.: A Mass-Distribution Criterion for Predicting the Effect of Control Manipulation on the Recovery From A Spin. NACA WR L-168, 1942. (Formerly NACA ARR, Aug. 1942.)

5. Neihouse, Anshal I., Lichtenstein, Jacob H., and Pepoon, Philip W.: Tail-Design Requirements for Satisfactory Spin Recovery. NACA TN 1045, 1946.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE RYAN X-13 AIRPLANE AS SIMULATED ON THE 1/18-SCALE SPIN MODEL

Overall length, ft	23.445
Wing:	
Span, ft	21.000
Area, sq ft	191.002
Sweep at leading edge, deg	60
Airfoil section -	
Root chord	NACA 65A008
Mean aerodynamic chord (measured in wing chord plane), in.	145.49
Leading-edge mean aerodynamic chord rearward of theoretical leading edge of wing (measured in wing chord plane), ft	6.06
Incidence (measured between wing chord plane and water line) -	
Root, deg	4
Dihedral, deg	0
Elevons:	
Total area, rear of hinge line, sq ft	22.095
Hinge line in percent of local chord:	
Root, percent	15
Tip, percent	15
Span, ft	6.135
Vertical tail:	
Total area, sq ft	47.205
Rudder, sq ft	7.065
Span, ft	9.150
Airfoil section	NACA 65A012

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TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS POSSIBLE ON THE RYAN X-13 AIRPLANE AND FOR THE LOADING TESTED ON THE MODEL

[Values given are full-scale, and moments of inertia are given about the c.g.]

Loading	Weight, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-feet^2			Mass parameters		
		$x/\bar{c}$	$z/\bar{c}$	Sea level	Altitude, 25,000 ft	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
Airplane values											
Normal weight - full fuel with wheels	6,958	0.3212	-0.0767	22.65	50.57	1727.5	4325.7	5109.3	-273×10^{-4}	-82×10^{-4}	355×10^{-4}
Normal weight - full fuel with hook	6,696	.3251	-.0884	21.81	48.70	1543.0	4042.0	4832.7	-272	-86	358
Landing weight - 25 percent fuel with wheels	5,908	.3232	-.0472	19.19	42.85	1254.8	4137.7	4747.8	-357	-76	433
Landing weight - 25 percent fuel with hook	5,646	.3317	-.0630	18.35	40.97	1108.1	3902.6	4482.0	-362	-75	437
Minimum weight - 5 percent fuel with wheels	5,628	.3236	-.0423	18.35	40.97	1157.6	4116.7	4651.7	-383	-70	453
Minimum weight - 5 percent fuel with hook	5,366	.3281	-.0554	17.40	38.87	981.5	3819.7	4353.5	-388	-73	461
Model values											
Normal weight - full fuel with hook	6,730	.2954	-.0758	21.91	48.93	1644	4064	4298	-263	-25	288

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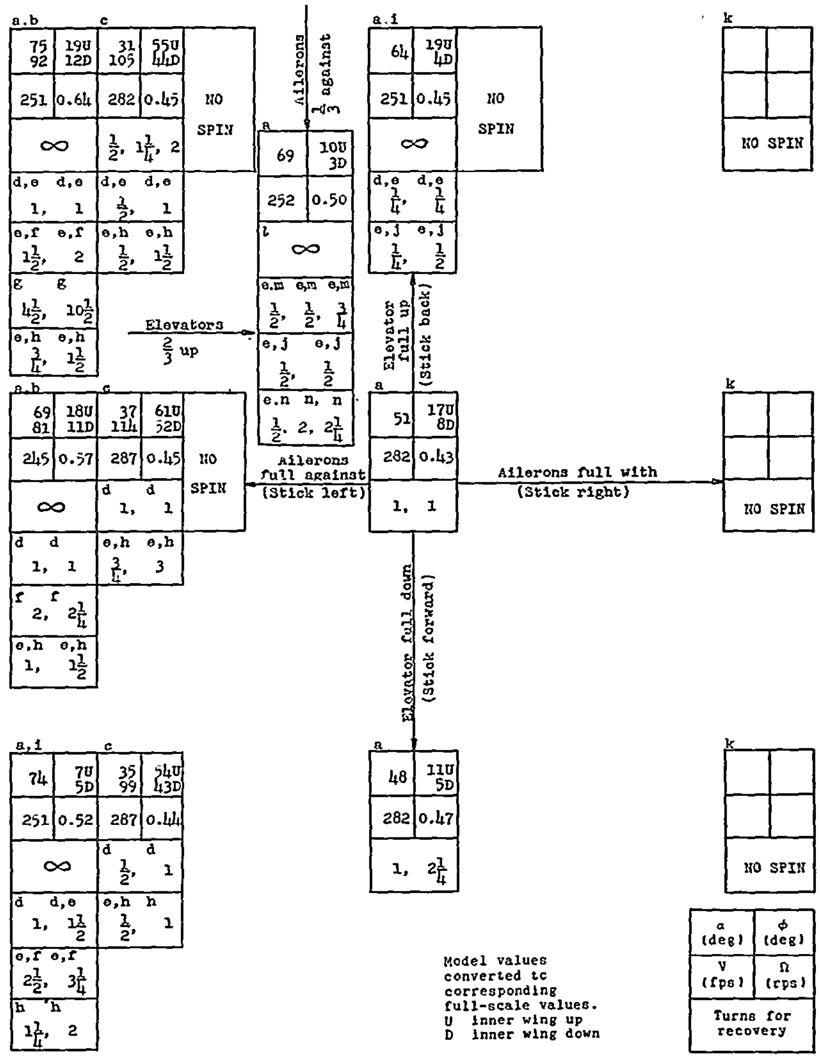
CHART 1.- ERECT-SPIN AND RECOVERY CHARACTERISTICS OF THE 1/18-SCALE

MODEL OF THE RYAN X-13 AIRPLANE

[Normal weight loading with hook, recoveries attempted by rapid full rudder reversal unless otherwise noted (recoveries attempted from, and steady-spin data presented for, rudder-full-with spins); erect spins to pilot's right]



[a]Fairly steady spin, average or range of values given.
[b]Three conditions possible.
[c]Violently oscillatory spin, range of values given.
[d]Recovery attempted by simultaneously reversing the rudder to full against the spin and moving the ailerons to full with the spin.
[e]After recovery, starts spinning in the opposite direction.
[f]Recovery attempted by simultaneously reversing the rudder to full against the spin and moving the ailerons to $\frac{1}{3}$ with the spin.
[g]Recovery attempted by simultaneously reversing the rudder to full against the spin and neutralizing the ailerons.
[h]Recovery attempted by moving the ailerons to full with the spin.
[i]Two conditions possible.
[j]Recovery attempted by moving the ailerons to $\frac{2}{3}$ with the spin.
[k]Enters a glide.
[l]Recovery attempted by reversing the rudder to $\frac{2}{3}$ against the spin.
[m]Recovery attempted by simultaneously reversing the rudder to $\frac{2}{3}$ against the spin and moving the ailerons to $\frac{2}{3}$ with the spin.
[n]Recovery attempted by simultaneously reversing the rudder to $\frac{2}{3}$ against the spin and moving the ailerons to $\frac{1}{3}$ with the spin.

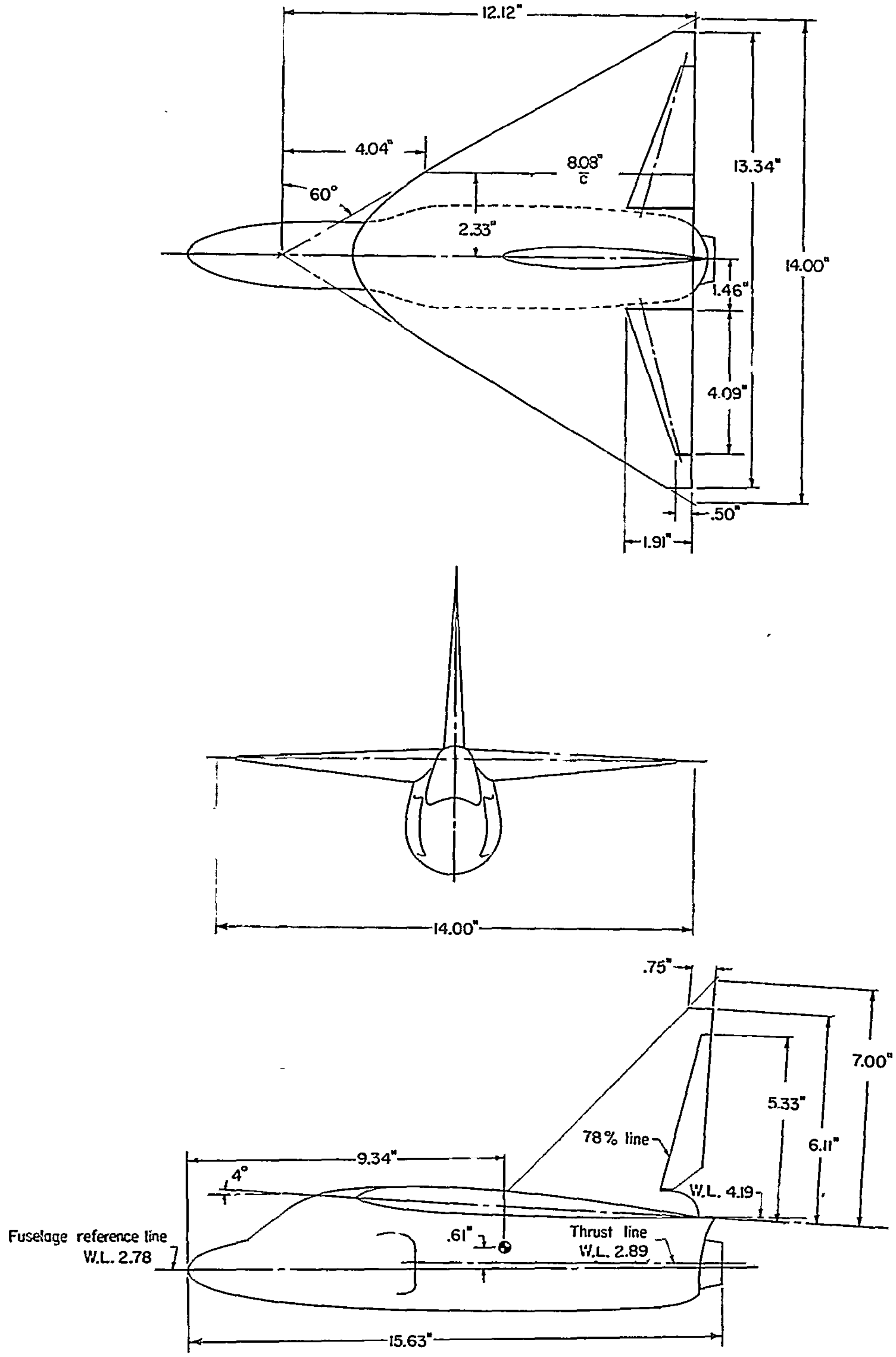


Figure 1.- Three-view drawing of a 1/18-scale model of the Ryan X-13 as tested in the Langley 20-foot free-spinning tunnel. Dimensions are model values. Center-of-gravity position shown is 29.5 percent mean aerodynamic chord.

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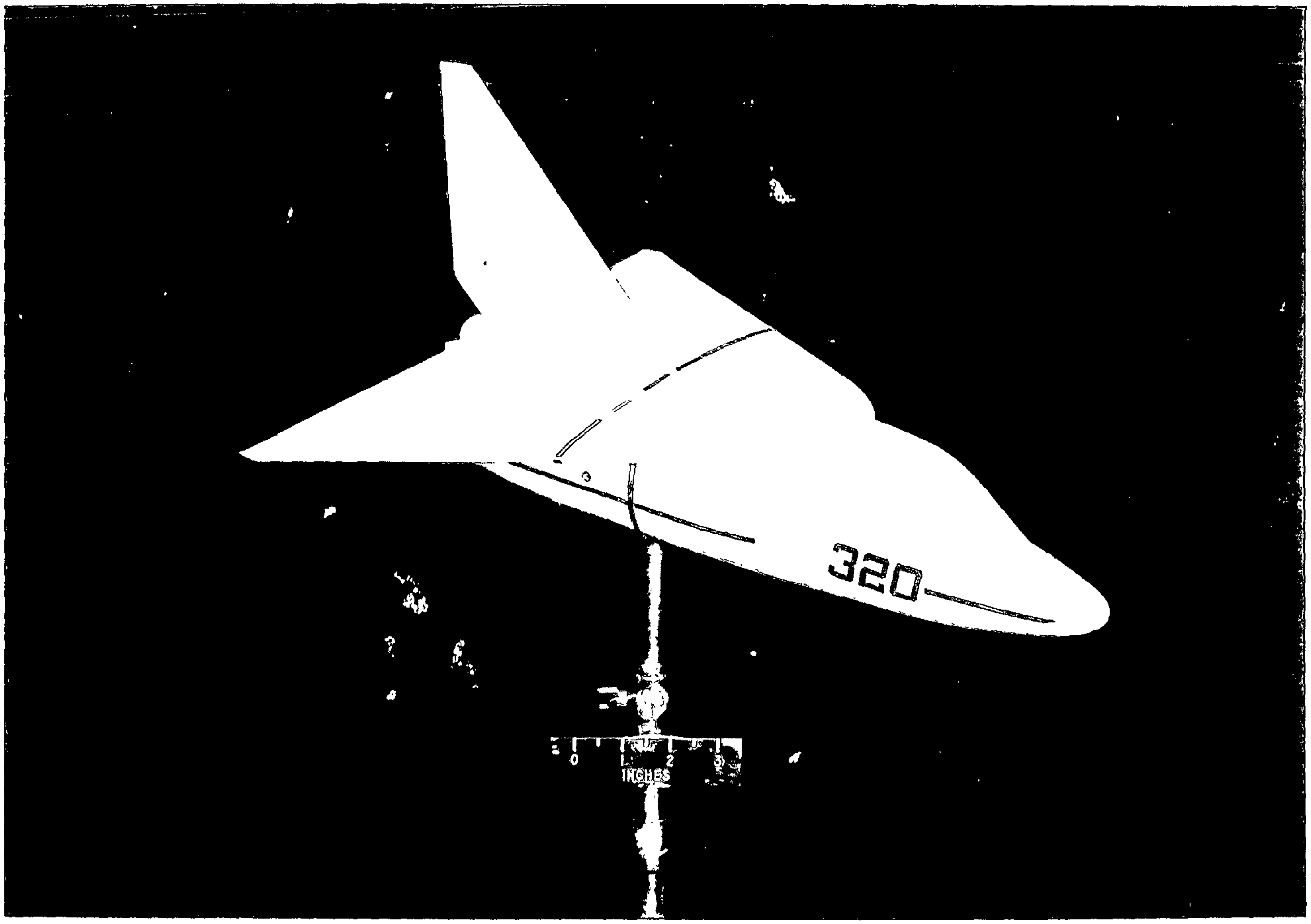

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Figure 2.- Photograph of the Ryan X-13 airplane model as tested in the Langley 20-foot free-spinning tunnel.